A Low-Complexity and Fast Adaptive Stokes-Space-Based Polarization Demultiplexing Technique for Optical Fiber Transmissions with Low Polarization Mode Dispersion

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Abstract: We propose a low-complexity fast adaptive polarization demultiplexing technique in Stokes-Space for optical fiber transmissions with low polarization mode dispersion. Experimental results of a polarization-multiplexed QPSK system confirm the feasibility of the proposed technique.

OCIS codes: (060.2330) Fiber optics communications, (060.4510) Optical communications.

1. Introduction

With the decreasing cost of integrated coherent optical receivers (CORs), the coherent solution with polarization multiplexing (PM) is becoming more and more attractive for metro-area optical fiber transmission systems (e.g. the inter-datacenter connections, long-reach PON, etc.) owing to its high receiver sensitivity and spectral efficiency [1]. Different from that designed for long-haul transmission systems, digital signal processing (DSP) for polarization demultiplexing (PolDemux) in coherent metro-area transmission systems should be optimized considering cost and power consumption, although the latter is with shorter fiber distance and lower chromatic dispersion (CD) and polarization mode dispersion (PMD). Fast convergence speed is another requirement for the PolDemux algorithm in metro-area transmission due to high flexibility and quick adaptation of the metro-area network [2]. Several schemes have been proposed to realized adaptive equalization algorithms with fast convergence speed under the assumption of low accumulated PMD, such as algorithms based on kalman filter [3], Stokes-Space (SS) polarization representation [4], etc. However, relatively high complexity makes these algorithms challenging in the practical implementations.

In this paper, we propose a low-complexity fast adaptive PolDemux technique in SS for optical fiber transmission systems with relatively low PMD. Experiments of PM-QPSK signals over 1600-km standard single mode fiber (SSMF) transmission have been implemented to confirm the feasibility of the proposed scheme.

2. Operating Principle and Simulation Results

SSMF model can be expressed as multiplication of a time-independent and a time-varying section as Eq.(1), assuming the CD can be totally compensated and the PDL and PMD can be neglected.

$$M = \underbrace{R_v(\Theta)}_{\text{time dependent}} \underbrace{R(\theta_2,\varphi_2)R(\theta_1,\varphi_1)}_{\text{time independent}} = \begin{bmatrix} \cos\Theta & \sin\Theta \\ -\sin\Theta & \cos\Theta \end{bmatrix} \bullet \begin{bmatrix} \cos\theta_2 & e^{-i\varphi_2}\sin\theta_2 \\ -e^{i\varphi_2}\sin\theta_2 & \cos\theta_2 \end{bmatrix} \bullet \begin{bmatrix} \cos\theta_1 & e^{-i\varphi_1}\sin\theta_1 \\ -e^{i\varphi_1}\sin\theta_1 & \cos\theta_1 \end{bmatrix} \quad (1)$$

where 2Θ, $2\theta_i$ and $2\varphi_i$ represent the time-varying polarization rotation angle, static azimuth and elevation angle, respectively. It can be seen from Eq.(1) that the time-varying and static polarization rotation parts are independent. As a result, polarization recovery for the time-varying and static rotation can be performed at different time.

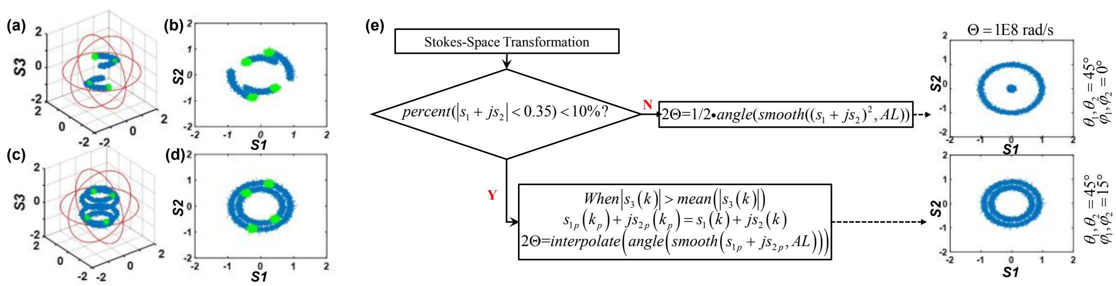

Fig.1(a-d) PM-QPSK with $\theta_1, \theta_2 = 45°; \varphi_1, \varphi_2 = 15°$, $\Theta = 2E6$ rad/s (a): in SS, (b): in s_1-s_2 plane; $\Theta = 1E8$ rad/s (c): in SS, (d): in s_1-s_2 plane (the blue points are with dynamic and static rotations, green points are only with static rotation) ; (e): Algorithm Flow Chart (AL is length for average)

In our proposed adaptive PolDemux technique, the time-varying polarization rotation is firstly recovered. The SS distributions as well as their projections on the s_1-s_2 plane of PM-QPSK signals with static and dynamic polarization rotations are shown in Fig.1(a-d). To compensate the dynamic rotations of the PM-QPSK signals, average is utilized to evaluate the rotation angle Θ on the projections plane. Considering the static rotation will have an impact on the signal distribution, as the two insets shown in Fig.2, two different ways to select the data for rotation angle evaluation are considered in the dynamic rotation compensation, which depend on whether the number of the data points near the origin of projection plane is less than 10% of the total number of data points. The detailed algorithm flow chart is shown in Fig.1(e). Distributions in projection plane like the right first picture in Fig.1(e), 2^{th} power of data is preferable for next average. When points distribute like the right second picture in Fig.1(e), another way of data selection is better for obtaining the rotation angle Θ.

After compensation of dynamic rotation, the static rotation could be easily recovered by the low-complexity SS PolDemux method in [5] cascaded with single channel equalization, due to the neglected PMD in the communication systems. Simulation with $\theta_1, \theta_2 = 45°$ and $\varphi_1, \varphi_2 = 15°$ is conducted to evaluate the proposed adaptive PolDemux technique (AL is 139), as the results are shown in Fig.2. In Fig.2(a), it plots number of samples for convergence against EVM under OSNR of 12dB near FEC of 3.8E-3 with dynamic rotation of 5E6 rad/s. In Fig.2(b), it depicts curves of speed of dynamic rotation against EVM under different OSNR. These simulation results show that our proposed scheme shows fast convergence and could bear high speed of dynamic rotations with low complexity.

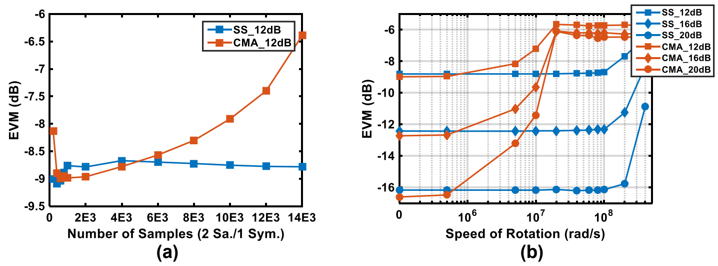

Fig.2(a): number of samples for convergence against EVM with 12dB OSNR and 5E6 rad/s rotation; (b): speed of rotation against EVM

3. Experimental results

We have demonstrated the experiments of back to back and 1600-km SSMF transmission of PM 28-GBaud QPSK, to investigate the feasibility of our scheme cascade with single channel equalization. To mimic the dynamic rotation, we add a dynamic rotation in DSP. 1600-km transmission setup shows in Fig.3(a). The light carries QPSK from arbitrary waveform generator (AWG), and is polarization multiplexed by polarization beam splitter (PBS), polarization maintaining fiber (PMF, for decorrelation) and polarization beam coupler (PBC). Then the amplified beam is sent to fiber recirculating loop system with an 80-km SSMF span. Later light filtered by optical band pass filter (OBPF) is coherent detected by integrated coherent receiver (ICR). Four electrical waveforms from ICR are recorded by oscilloscope for further DSP. From experimental results in Fig.3(b-c) our scheme (AL is 139) could bear fast dynamic rotation under low PMD. With more taps for equalization, our scheme has better performance.

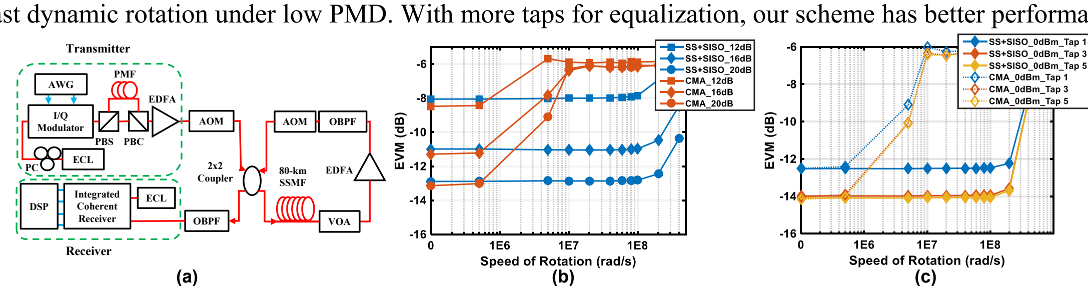

Fig.3(a): Setup; (b): Back to back; (c): 1600-km transmission

4. Acknowledgements

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5. References

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